Weather Impacts on Transport Systems and general adaptation strategies

Claus Doll, Fraunhofer-ISI, Karlsruhe, Germany, Northwestern University, Transportation Center
The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe.

It undertakes applied research of direct utility to private and public enterprises and of wide benefit to society.

Some numbers:
• 80 Research institutions
• 60 Institutes
• 18 000 employees, primarily with natural or engineering science training
• € 1.66 billion research volume annually,
The Fraunhofer Institute for Systems and Innovation Research ISI

- studies how innovations originate, which actors are to be integrated, who benefits from them and how they can be promoted
- evaluates economic, social and political potentials and the limits of technical innovations
- helps decision-makers in industry, science and politics in setting a strategic course
- utilizes the newest theories, models, social-science measurement instruments and databases and constantly develops them further
- handles circa 350 research projects per year
- has influenced the German innovation landscape for more than 35 years as no other research institution has
Facts and Figures

Broadly based know-how

Number of staff: 190
(125 scientists)

Clients*

Budget 2010:
approx. € 20 million

350 research and consultancy projects per year

* as a percentage of the total
## Competence Centers of Fraunhofer ISI

<table>
<thead>
<tr>
<th>Business Unit</th>
<th>Description</th>
</tr>
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</table>
| Industrial and Service Innovations | - Industrial Innovation Strategies and Systems  
- Innovative Production Systems and Value Chains  
- Industrial Services |
| Energy Technology and Energy Systems | - Energy Efficiency  
- Energy Economy  
- Demand Analysis and Projections |
| Policy and Regions | - Policy and Evaluation  
- Regions and Clusters  
- Innovation Indicators |
| Sustainability and Infrastructure Systems | - Renewable Energies  
- Energy and Climate Policy  
- Electricity Markets and Infrastructures |
| Energy Policy and Energy Markets | - Futures Research and Foresight  
- Management of Innovations and Technologies  
- Strategies for Material Technologies |
| Innovation and Technology Management and Foresight | - Water Resources Management  
- Transportation Systems  
- Systemic Risks  
- Sustainability Innovations and Policy |
| Emerging Technologies | - Biotechnology and Life Sciences  
- Innovations in the Health System  
- Information and Communication Technologies |
Current research of the Business Area for Transportation Systems (Selection)

- WEATHER – Impacts of weather extremes and climate change on European transport Systems (EC, DG-Research)
- Current State and Future of Electro-Mobility in Germany and Europe (Federal Parliament, Office for Technology Appraisal)
- Future of the Automotive Industry (Federal Parliament, Office for Technology Appraisal)
- GHG-TransPoRD – Long-Term Strategy for CO2 Emission Reduction in the EU (EC, DG-Research)
- External Costs of Transport for Europe 2008 (International Union of Railways UIC)
- Impacts of Longer and Heavier Trucks on Rail Wagon Load and Combined Transport (Community of European Railways CER)
- Mobility Strategy for Munich Airport (Munich Airport Society)
OVERVIEW OF THE WEATHER PROJECT STRUCTURE
Disasters by type and country

- Estimated damage costs per disaster type, country and capita
- Most affected: large European central / south-western countries
- Remarkably low relevance in Scandinavian countries
- Most relevant categories: Storms and floods
- Possible bias by national cultures to reporting damages; incompleteness of damage records
Significant data only since 1950

Options / culture of data reporting and recording.

Slope of estimated damages much more significant:

- Severity of extremes?
- Transport network density?
- Availability of past damage records?
WEATHER core objective

Determine the physical impacts and the economic costs of extreme weather events on transport systems and identify the costs and benefits of suitable adaptation and emergency management strategies.

Duration: November 2009 – April 2012

Funding: 7th framework program of the European Commission, DG-RESEARCH

<table>
<thead>
<tr>
<th>Participant organisation name</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fraunhofer Society, Institute for Systems and Innovation Research (ISI) and Institute for Transportation and Infrastructure Systems (IVI)</td>
<td></td>
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<tr>
<td>Centre for Research and Technology Hellas, Hellenic Institute for Transportation (CERTH-HIT)</td>
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<tr>
<td>Société de Mathématiques Appliquées et de Sciences Humaines - International research Center on Environment and Development (SMASH-CIRE)</td>
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<tr>
<td>Center for Disaster Management and Risk Reduction (CEDIM), Karlsruhe Institute of Technology</td>
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<tr>
<td>Institute of Studies for the Integration of Systems (ISIS)</td>
<td></td>
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<tr>
<td>Herry Consult GhmH</td>
<td></td>
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<tr>
<td>Agenzia regionale per la Prevenzione e l'Ambiente dell'Emilia Romagna (ARPA-ER)</td>
<td></td>
</tr>
<tr>
<td>NEA Transport research and training</td>
<td></td>
</tr>
</tbody>
</table>
# Work Packages and Schedule

| Project duration | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|------------------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| WP0A: Administrative project management |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | PR1 |  |  |  | PR2 |  |  |  |
| WP0B: Scientific management and dissemination |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | M1 | M2 | M3 |  |  |  |  |  |  |  |
| WP1: Weather trends and economy-wide impacts |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | WS1 | D1 | JWS |  |  |  |  |  |  |  |
| WP2: Vulnerability of transport systems |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | WS2 | D2 |  |  |  |  |  |  |  |
| WP3: Crisis management and emergency strategies |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | WS3 | D3 |  |  |  |  |  |  |  |
| WP4: Adaptation options and strategies |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | WS4 | D4 |  |  |  |  |  |  |  |
| WP5: Governance, incentives and innovation |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | WS5 | D5 |  |  |  |  |  |  |  |
| WP6: Case studies |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | WS6 | D6 |  |  |  |  |  |  |  |
| WP7: Policy conclusions |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | WS7 | D7 |  |  |  |  |  |  |  |  |
VULNERABILITY ASSESSMENT
Deliverable 2
"The Vulnerability Assessment" in brief

Analytical steps:
- Transport sector observations
- Insurance and general statistics
- Media reports

Infrastructure damage costs
Vehicle damage costs
User time costs
User health costs

House numbers of average annual costs

Dimensions:
- Transport modes:
  - Road
  - UPT
  - Rail
  - CT
  - IWW
  - Maritime
  - Aviation

- Weather categories:
  - Rain, hail
  - Floods
  - landslides
  - Cold, snow, ice
  - Heat, drought
  - Wildfires
  - Storms

- Climate zones

Fraunhofer
Core question: What is “extreme”? 

**Meteorological definition**: Events exceeding the 90\textsuperscript{th} or 95\textsuperscript{th} percentile of severity or duration of long-term averages (e.g. the 10\% longest dry spells, 10\% multi-day-periods with lowest temperatures, etc.) Related to annual indicators → 10 year / 20 year event or return period

**Impact-related definition**: events entailing consequences which exceed the managerial capacity or resources of the local area affected (i.e. requiring support from supra-regional entities) or which are causing substantial damages to assets or human health or lives. Somehow arbitrary but easy to manage approach

**Selected** for the WEATHER project: Impact-related definition
What is assessed?

Meteorology → extreme = above 90 percentile of duration or severity of long-term average

→ I.e. 90% of weather variations are normal and are not accounted for

→ only those events exceeding the 90th percentile are accounted

→ Rather modest results compared to complete damage accounting
## Motivation: Various recent hazardous events

<table>
<thead>
<tr>
<th>Event</th>
<th>Area</th>
<th>Road</th>
<th>Rail</th>
<th>Air</th>
<th>Shipping</th>
<th>Total Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy rain, flood, November 2009</td>
<td>UK and Ireland</td>
<td>Collapse and drop of bridges, closed A roads, floated cars, chaos</td>
<td>Bridge collapse, Disrupted services</td>
<td>No reports</td>
<td>Suspended lake cruises, 20 sunk boats,</td>
<td>UK, all sectors: € 390 mill.</td>
</tr>
<tr>
<td>Extratrop. Storm Xynthia, 02/2010</td>
<td>DE, FR, BE, ES, PT</td>
<td>Bridgesdestroyed, flooded roads, floated cars,</td>
<td></td>
<td>Temporal airport closures (CDG),</td>
<td></td>
<td>FR: €1320; 64 killed (FR: 53)</td>
</tr>
<tr>
<td>Flood and mudslide, Feb. 2010</td>
<td>Madeira, Portugal</td>
<td>Bridgesdestroyed, flooded roads, floated cars,</td>
<td></td>
<td>Airport closed, flight delays</td>
<td></td>
<td>€ 1500 mill., 34 casualties</td>
</tr>
<tr>
<td>General floods May – Aug. 2010</td>
<td>Central Europe (PL, CZ, HU et al.)</td>
<td>PL: Secondary roads flooded. HU: several villages cut off</td>
<td>PL: Submerged rail station, broken bridge</td>
<td></td>
<td></td>
<td>€2900 mill. (PL 88%), 66 killed</td>
</tr>
<tr>
<td>Summer heat July 2010</td>
<td>Middle Europe, southern Scandinavia</td>
<td>Pavement deterioration, drivers harmed at Gotthard tunnel</td>
<td>Evacuation of ICE trains, DB: €500 compensation per injured pass.</td>
<td>-</td>
<td>-</td>
<td>No information</td>
</tr>
<tr>
<td>Volcanic ash cloud</td>
<td>North and middle Europe</td>
<td></td>
<td></td>
<td>Airspace closure, late &amp; cancelled flights worldwide</td>
<td>Airlines: € 160 mill./day ,</td>
<td></td>
</tr>
<tr>
<td>Winter 2010/11</td>
<td>Mid Europe and UK</td>
<td>Accidents, closed or unmaintained roads, high costs</td>
<td>Cancelled trains + delays, stuck passengers</td>
<td>11000 cancelled flights, delays, passengers to rail</td>
<td>Frozen channels, suspension of shipping</td>
<td>No estimate available</td>
</tr>
</tbody>
</table>
The results: which impacts are most costly and what is the biggest cost driver?

Problems: bias by selected media + input data uncertainties
But: report assessment indicates order of magnitude of the problem by type of incident

Results:

- Germany highest costs → density of reports
- Italy only storms → not plausible
- Floods most relevant → many countries + damage of assets
- Heat: no reports from southern Europe

![Total costs 2000 - 2010 by media reports](chart.png)

Legend:
- Blue: Total Infra Assets (€K)
- Red: Total infra Operations (€K)
- Orange: Total Vehicle Assets (€K)
- Green: Total fleet Operations (€K)
- Purple: Total User Time (€K)
- Yellow: Total Health & Life (€K)
Road – selected findings from literature

Crash rates by weather type in the US 1995 - 2005

Winter maintenance costs in relation to annual snow and ice days on German motorways and federal roads
Road Vulnerability – the Hybrid Approach

- **Incident Database (IDB)**
  - 950 media and transport operator reports +
  - Assessment by standard incident categories

- **Extremes Elasticity Model (EEM)**
  - Cost elasticity evidence from literature +
  - Meteorological indices of extremes

Overview of the availability of cost estimates in road transport due to extreme weather conditions:

- **EEM**: Extremes elasticity model
- **IDG**: Incident Database

<table>
<thead>
<tr>
<th>Generalisation</th>
<th>Rainfalls</th>
<th>Floods / flash floods</th>
<th>Mass movements</th>
<th>Extratrop. cyclones</th>
<th>Storm surges</th>
<th>Hail and hail storms</th>
<th>Frost periods</th>
<th>Snow</th>
<th>Winter Storms</th>
<th>Heat periods</th>
<th>Droughts</th>
<th>Wild fires</th>
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<tbody>
<tr>
<td>Infrastructure assets</td>
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<td>Infrastructure operations</td>
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<td>Vehicle assets</td>
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<td>Transport service operations</td>
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<td>Safety issues</td>
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<tr>
<td>Congestion and delays</td>
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</tbody>
</table>

Data sources:
- EEM
- IDB
- Both
- No data
- Irrelevant
Specific look on road (1): main problem flood damages to infrastructures

Results:
- Total costs: € 1.8 bill. p.a.
- Highest costs for winter conditions, followed by rain and floods (including landslides)
- Most affected element: infrastructure assets

Results partly driven by data availability: poor consideration of southern countries and heat-related impacts
Specific look on road (2): mid Europe and Alps most costly

Most affected regions: mid Europe (DE, Benelux) and Alpine area

Most relevant cost driver across all regions: rain and flood
Network criticality assessment: where does the cut of road networks hurt most?

Main features
- Transport models VISUM and TRANS-TOOLS
- Algorithm identifying the importance of single links
- Application to Greece, Germany and the Netherlands

General findings
- Most critical access roads to big agglomeration areas
- Partly high relevance of interurban links in sparsely populated boarder areas.
- Similar results for densely populated NL and for rural German and Greek areas.
- Approach applicable to other modes, too
Railways –
Selected evidence from literature

Rail buckling in the UK:
Several thousand delay hours
– quality issues of rail
construction and
maintenance standards?

Importantly in mountain areas: land
slides and flash floods. No
systematic database by European
rail infrastructure organisations.
**Rail – Results on average costs per category of extreme**

**Basis:** Assessment of incident reports in a few countries with access to operator data.

Presentation for selected categories of extremes by max., min., average and median costs per incident.

**Results:**
- by far most relevant permanent rain with consequences (= major floods)
- No evidence for relevant heat-inflicted costs

<table>
<thead>
<tr>
<th></th>
<th>Heavy rainfalls with consequent events</th>
<th>Permanent rainfalls with consequent events</th>
<th>Thunder-storms</th>
<th>Winter-storms</th>
<th>Avalanches</th>
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<tbody>
<tr>
<td><strong>capital costs</strong></td>
<td>min</td>
<td>0,00</td>
<td>1,97</td>
<td>0,00</td>
<td>0,00</td>
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<tr>
<td></td>
<td>max</td>
<td>2,81</td>
<td>50,37</td>
<td>0,04</td>
<td>0,04</td>
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<tr>
<td></td>
<td>average</td>
<td>0,73</td>
<td>18,13</td>
<td>0,02</td>
<td>0,01</td>
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<td>median</td>
<td>0,26</td>
<td>2,06</td>
<td>0,02</td>
<td>0,00</td>
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<tr>
<td><strong>optrational costs</strong></td>
<td>min</td>
<td>0,15</td>
<td>3,40</td>
<td>0,49</td>
<td>0,20</td>
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<tr>
<td></td>
<td>max</td>
<td>18,82</td>
<td>40,29</td>
<td>0,63</td>
<td>5,94</td>
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<td></td>
<td>average</td>
<td>3,84</td>
<td>16,62</td>
<td>0,56</td>
<td>1,65</td>
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<tr>
<td></td>
<td>median</td>
<td>1,56</td>
<td>6,17</td>
<td>0,56</td>
<td>0,58</td>
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<td><strong>user costs</strong></td>
<td>min</td>
<td>0,10</td>
<td>2,01</td>
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<td>max</td>
<td>11,96</td>
<td>23,79</td>
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<td>2,48</td>
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<td>average</td>
<td>2,44</td>
<td>9,84</td>
<td>0,29</td>
<td>0,86</td>
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<td>median</td>
<td>1,01</td>
<td>3,73</td>
<td>0,29</td>
<td>0,40</td>
</tr>
<tr>
<td><strong>Total costs</strong></td>
<td>min</td>
<td>0,26</td>
<td>7,37</td>
<td>0,82</td>
<td>0,35</td>
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<td>max</td>
<td>31,97</td>
<td>114,46</td>
<td>0,93</td>
<td>8,42</td>
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<td></td>
<td>average</td>
<td>7,00</td>
<td>44,60</td>
<td>0,87</td>
<td>2,52</td>
</tr>
<tr>
<td></td>
<td>median</td>
<td>2,69</td>
<td>11,96</td>
<td>0,87</td>
<td>1,40</td>
</tr>
</tbody>
</table>
Rail – Generalisation of results

1. Allocation of the 4 incident categories to WEATHER standard categories
2. Number of extremes from EEA database for 2000 – 2010
3. Selection of unit cost factor (between min and max) by total damage of extreme
4. “Back of the envelope” estimate → no regional differentiation

<table>
<thead>
<tr>
<th>Category</th>
<th>Severity</th>
<th>#</th>
<th>Average costs (mill. € / event)</th>
<th>Total annual mean costs mill. € p.a.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Infra-structure</td>
<td>Operations</td>
</tr>
<tr>
<td>Avalanches</td>
<td>Major</td>
<td>9</td>
<td>0.04</td>
<td>3.76</td>
</tr>
<tr>
<td>Storms</td>
<td>Very large</td>
<td>32</td>
<td>0.01</td>
<td>1.65</td>
</tr>
<tr>
<td></td>
<td>Major</td>
<td>41</td>
<td>0.01</td>
<td>1.65</td>
</tr>
<tr>
<td>Floods</td>
<td>major landslides</td>
<td>54</td>
<td>0.73</td>
<td>3.84</td>
</tr>
<tr>
<td></td>
<td>Major floods</td>
<td>55</td>
<td>18.13</td>
<td>16.52</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Aviation—
Selected evidence from literature

Delays from EUROCONTROL database: peaks in extreme winters 2009 – 2011 clearly visible

Aviation safety: Probably minor impact of weather in commercial aviation, but considerable fatalities in general aviation. Detection of real causes difficult with current data sets.

Causes of Fatal Aviation Accidents by Decade (percentage)

- Other Cause
- Sabotage
- Mechanical Failure
- Weather
- Other Human Error
- Pilot Error (mechanical related)
- Pilot Error (weather related)
- Pilot Error

Data source: EUROCONTROL 2011

Av. departure delay

Data source: EUROCONTROL 2011

Causes of delay per movement and share of delay groups in commercial air transport 2007 - 2010
Aviation–
Some results for Europe

Equally important: winter conditions and storms.
Most affected user time losses and fleet operations.

Regional context rather artificial for some cost categories (delays + operating costs) due to level of data accessibility.
Probably most affected Mid Europe (ME), France (FR) and the British Islands (BI) due to their fluctuating climate conditions.
The results: which impacts are most costly and what is the biggest cost driver?

Focus of modal studies is extremely different:

- EU-wide generalisation of costs from a sample of countries (road, CT and aviation)
- Concentration of a set of relevant core countries (maritime and IWW)
- Detailed assessment of selected events and cases (rail)
- Reporting of some selected observations (urban and intermodal passenger transport)

Results:

- Total annual costs: €2.2 billion,
- Most costly extreme: rain and floods.
- Biggest stakeholders affected: Infra assets and users’ costs (delays and accidents)
Hot spots in current damage levels: average costs by passenger-kilometer

Average annual costs in the road sector 1998 -

Average annual costs in the rail sector 1998 -

Average annual costs in the air sector 1998 - 2010
FORECASTING DAMAGE COSTS
European Scenario based on ENSAMBLIES projections

The ENSEMBLES probabilistic projection of 10\textsuperscript{th} (a) and 90\textsuperscript{th} (b) percentile of summer mean air temperature (JJA-10\textsuperscript{th} and 90\textsuperscript{th} T\textsubscript{mean}) over Europe under the A1B emission, period 2080–2099 relative to the 1961–1990 Focus on IPCC and related publications → detailed scenarios in D1

Statistical Downscaling for Northern Italy

Probability density functions (PDF) for winter and summer season 2021-2050 & 2071-2011
Transport Sector Forecasts to 2050

- Basis: European System Dynamics Model ASTRA: GHG-TransPoRD Base Scenario until 2050
- Model Outputs: passenger-km and ton-km for road rail/navigation and aviation → composite vulnerability measure = pkm + 0.3 * tkm according to values of travel time savings.
- Infrastructure assets: estimated growth according to pkm / tkm growth and network saturation (road: medium, rail: low, air: high)
Forecast results to 2050

Link between weather patterns and transport costs by elasticity values:

- 0.5 for winter impacts as primary problem is onset of ice and snow conditions
- 0.8: hydrological and storm events as locally specific with limited leaning effects
- 1.5 for heat and drought as in particular longer durations cause high costs

**Results**: development of average costs (€/pkm-tkm) due to weather extremes

<table>
<thead>
<tr>
<th>Sector</th>
<th>AL</th>
<th>BI</th>
<th>EA</th>
<th>FR</th>
<th>IP</th>
<th>MD</th>
<th>ME</th>
<th>SC</th>
<th>EUR29</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road</td>
<td>-5%</td>
<td>3%</td>
<td>5%</td>
<td>54%</td>
<td>-17%</td>
<td>-13%</td>
<td>-21%</td>
<td>12%</td>
<td>5%</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>-14%</td>
<td>9%</td>
<td>-1%</td>
<td>71%</td>
<td>-19%</td>
<td>-8%</td>
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ADAPTATION STRATEGIES AND TECHNOLOGIES
Preparatory tasks:
Hot spot analyses by sector and mode
Damage costs / vulnerability forecast until 2050 / qualitatively until 2011

Sector adaptation analyses
Database of measures by:
Infrastructure technology
Vehicle technology
System operations
Transport planning

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<tr>
<th>Measure</th>
<th>Short title / description</th>
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<td>Sector</td>
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<td>Mode</td>
<td>Details to the transport mode addressed by the measure</td>
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<tr>
<td>Hazard</td>
<td>Detailed weather extremes addressed by the measure</td>
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<tr>
<td>Area</td>
<td>Detailed geographical characteristics for the measure</td>
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<td>Impact</td>
<td>Network-km, assets, people potentially affected</td>
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<tr>
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<tr>
<td>Transferrability</td>
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<td>Sources</td>
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</table>
Example 1: Planning for multi-functional space in urban areas

- Netherlands: large parts under sea level.
- Planning focus changed from technology (building materials) to sustainable planning strategies.
- Multifunctional space provides reservoirs for flood waters to be temporarily stored
Example 2: Infrastructure Technologies in Public Transport

• More heat waves requires advanced air conditioning for waiting passengers in stations
• Investments needed to reduce out-of-service times in the London underground as in summer times trains push in hot air inside
• Air conditioning of bus stations in Dubai and Bandar Kinrara → sustainability?
Example 3: Vehicle technology in public transport

- Innovative amphibious bus in Glasgow replacing ferries. Option for enhanced evacuation in emergency situations (left)
- Aerodynamics improvements of vehicles against side winds (right)
Example 4: Operations – interlinkage of processes in air transport (WIMS)

- Automatic linking of advanced weather information management systems (WIMS) to operational processes
- Next Generation ATM → better use of capacity and more robustness against weather extremes.
Workshop 3: Adaptation Strategies

May 20th Rotterdam, 22 external experts from stakeholders and research

Key messages:
• Now consideration of climate issues in planning 2100 due to long life of infrastructures
• Some technical measures are at low costs, problem of acceptance
• Operators often still ignore the relevance of Climate change on their business
• Costs and risk reduction potential constitute the most relevant assessment criteria

Expert votes for MCA weighting criteria
(n = 31, total vote = 100)
Multi Criteria Assessment Results

5 criteria:
costs = affordability
feasibility
flexibility
wider impacts
risk reduction
Scale 0..3

4 main categories
in 11 sub-categories
317 single measures

Assessment results by adaptation categories
Range of scores: 0 .. 3

<table>
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<tr>
<th>Category</th>
<th>Incentives and information</th>
<th>Supervision and maintenance</th>
<th>Investments</th>
<th>Detection and communication</th>
<th>Engineering</th>
<th>Maintenance</th>
<th>Raising preparedness</th>
<th>Co-operation strategies</th>
<th>System redesign</th>
<th>General protection measures</th>
<th>Network redesign</th>
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Conclusions on adaptation strategies

Most promising strategies identified:

• **Training, incentives and information strategies** to be applied to company staff as well as to management units. Easily feasible, very flexible, providing wider impact (team building) at reasonable costs.

• **Detection and communication solutions with ICT technologies**: Damage prevention through early warning, reasonable costs and commonly easily feasible. Most technologies do exist already now.

• **Co-operation strategies**: Low cost and wider secondary impacts to prepare companies and industries for very different kinds of threats (global demand and supply shortages, different types of transport system failures, etc.).

Most technologies and organizational options do exist already now. Climate change and increasing weather extremes are only one out of many driving forces to implement them. Many infrastructure-related engineering measures can be implemented at low or no costs through standard maintenance cycles.
CASE STUDIES AND THE INTERNATIONAL PANEL
Case studies, regions and modes

1. Flood of 2002 in eastern Germany
2. Summer heat 2007 in southern Europe
3. Flooding of the rail link Vienna - Prague in 2006
5. Heavy snow on Alpine roads in northern Italy
6. Rhine shipping during 2003 summer heat
# International Panel of Experts

<table>
<thead>
<tr>
<th>Individuals and institutions subcontracted</th>
<th>Topics of contributions foreseen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Markus Maibach, INFRAS (Switzerland)</td>
<td>Assessment of Swiss adaptation strategy from the perspective of transportation</td>
</tr>
<tr>
<td>Prof. Kiril Karagyozov, Higher School of Transport (Bulgaria)</td>
<td>Winter and flood events in Bulgaria: funding opportunities and policy implementation from the perspective of New Member States</td>
</tr>
<tr>
<td>Prof. Joseph L. Schofer, Pablo Durango-Cohen, Northwestern University (USA)</td>
<td>Ileen and similar event hitting the New York subway system: Damages, level of preparedness and lessons learned</td>
</tr>
<tr>
<td>Dr. Prem Chhetri, Melbourne University (Australia)</td>
<td>Heat impacts and adaptation strategies in Australian transport sectors</td>
</tr>
<tr>
<td>Dr. Kenneth Kuhn, Canterbury University (New Zealand)</td>
<td>Flood impacts on major road links in New Zealand: Damage assessment and policy analyses.</td>
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Contributions until November 2011 for inclusion in D6
Thanks!

www.weather-project.eu

Contact: claus.doll@isi.fraunhofer.de
WEATHER CASE STUDY REGIONS
AND MODES OF TRANSPORT

WEATHER EXTREMES: IMPACTS ON
TRANSPORT AND EUROPEAN REGIONS